Industrial Crops and Products 76 (2015) 174–187

Contents lists available at ScienceDirect

Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

Essential oils for the development of eco-friendly mosquito larvicides: A review

Roman Pavela

Crop Research Institute, Drnovska 507, 161 06, Prague 6-Ruzyne, Czech Republic

ARTICLE INFO

Article history:
Received 2 March 2015
Received in revised form 15 June 2015
Accepted 20 June 2015

Keywords:
Botanical insecticides
Larvicides
Essential oils
Mosquitoes
Terpenes

ABSTRACT

Mosquitoes serve as vectors for a wide variety of human and veterinary pathogens and parasites and cause extensive morbidity and mortality, and are a major economic burden within disease-endemic countries. Protection against mosquitoes is based on insecticides. However, the negative effects of synthetic insecticides have become the main impetus for an expeditious search for new alternatives, which would be acceptable for both the environment and public health. The use of insecticides based on plant extracts is currently highly promising from the alternatives of protection against insects. Many plant extracts that contain substances with insecticidal effects also include a large group of the so-called essential oils (EOs).

The intensity of research focused on new EOs that could become suitable active substances for new botanical larvicides has been growing over the past few decades.

The purpose of this review was to evaluate the current research on using EOs as potential larvicides based on their chemical composition and biological efficacy. The selected plants (their EOs), as the case may be, were therefore required to meet two essential conditions: (i) LC50 ≤ 100 ppm; and (ii) their chemical composition had to be known.

In total, 122 plant species from 26 families were selected from the available literature. However, more than 2/3 of the plants (68.8%) were from only 5 families: Lamiaceae, Cupressaceae, Rutaceae, Apiaceae, and Myrtaceae.

Considering the above-estimated LC50 value as the main criterion of efficacy, 77 showed LC50<50 ppm. Some of these efficient EOs were obtained from aromatic plants also grown commercially on relatively large areas, with a good technology of cultivation (e.g., *Pimpinella anisum*, *Coriandrum sativum*, *Foeniculum vulgare*, *Mentha longifolia*, *Ocimum basilicum*, *Thymus* spp., *Eucalyptus* spp., *Piper* spp., etc.). Such plants could become a suitable source of active substances for potential botanical larvicides. Only seven plants (*Blumea densiflora*, *Auxemma glazioviana*, *Callitris glaucophylla*, *Cinnamomum microphyllum*, *Cinnamomum mollissimum*, *Cinnamomum rhyncophyllum*, *Zanthoxylum oxyphyllum*) can be considered significantly most efficient, given that LC50<10 ppm has been estimated for their EOs. These EOs contained less common substances, predominantly from the group of sesquiterpenes, aromatic acids and ketones.

Contents

E-mail address: pavela@vurv.cz

http://dx.doi.org/10.1016/j.indcrop.2015.06.050
0926-6690/

1. Introduction

Mosquitoes serve as vectors for a wide variety of human and veterinary pathogens and parasites. Vector-borne diseases (malaria, dengue, leishmaniasis, filariasis, and Chagas disease) cause extensive morbidity and mortality, and are a major economic burden within disease-endemic countries.

Malaria, in particular, continues to impart a major disease burden on infants and young children in endemic regions. There are 350–500 million cases of malaria annually, with at least 1 million deaths, and 90% of mortality attributed to malaria is experienced by infants and young children, the vast majority in sub-Saharan Africa (WHO, 2009, 2012b; Tolle, 2009).

Likewise, dengue ranks among the most important mosquito-borne viral diseases in the world. In the last 50 years, the incidence has increased 30-fold. An estimated 2.5 billion people live in over 100 endemic countries and areas where dengue viruses can be transmitted. Up to 50 million infections occur annually with 500,000 cases of dengue haemorrhagic fever and 22,000 deaths, mainly among children (WHO, 2012a).

In the past decade, West Nile virus has emerged in the Americas, becoming endemic throughout the region; chikungunya, a formerly obscure arbovirus endemic to East Africa, has also emerged, causing millions of cases in the Indian Ocean basin and mainland South and Southeast Asia; and the Japanese encephalitis virus has expanded its range in the Indian subcontinent and Australasia, where it chiefly affects children (Tolle, 2009).

Protection against insect vectors and especially against mosquitoes is based on three essential modes of approach:

i) Protection against adults based on killing them. This is the most widespread and one of the most efficient modes of protecting people in their homes. Much of the recent decrease in the global malaria burden has been achieved through the scale-up of vector-control interventions, particularly the use of insecticides for treating mosquito nets – long-lasting insecticidal nets and insecticide-treated nets – and other materials, as well as for indoor residual spraying.
ii) Protection based on preventing insects from sucking blood using repellents. Repellents are substances of synthetic (DEET) or natural (e.g., essential oils) origin that repel females, thereby preventing them from sucking blood, and thus, also from transmitting any infection. However, although relatively efficient and popular, this indirect protection method often provides lower efficacy, considering the need to repeat repellent application in regular intervals of several hours.
iii) Reduction of the population density of adults. This category includes two principal strategies: The first is based on elimination of natural stands suitable for larval hatching and development (e.g., by dewatering natural or artificial reservoirs and small pools). The second strategy is larval source management (LSM), which utilizes insecticides or larvicides to kill mosquito larvae; alternatively, natural predators that naturally feed on mosquito larvae (for example, some fish species) can be used for larger water reservoirs (lakes, ponds) (Seyoum et al., 2003; Walker and Lynch, 2007; Santana-Méridas et al., 2012; WHO, 2006, 2009, 2012c).

In the early twentieth century, larviciding and environmental management were the only tools available to contain malaria. The historical literature and more recent reviews of this approach show that anti-larval mosquito control measures were powerful tools against malaria. Significantly, LSM contributed to all successful eradication efforts and successful vector-control programmes worldwide. Mosquito larvae are relatively immobile and often readily accessible. By targeting the larval stages, mosquitoes are killed 'wholesale' before they disperse to human habitations. Mosquito larvae, unlike adults, cannot change their habitat to avoid control activities (Fillinger and Lindsay, 2011).

Today, the use of larvicides faces several serious problems. Besides the negative effects of synthetic insecticides on the environment and non-target organisms, including man (Hodgson and Levi, 1996), the development of resistant mosquito populations in particular is one of the most serious problems (WHO, 2012c).

Insecticide resistance is viewed as an extremely serious threat to crop protection and vector control, and is considered by many parties, including industry, the WHO, regulatory bodies and the public, to be an issue that needs a proactive approach (Hemingway and Ranson, 2000; McCaffery and Nauen, 2006; Nauen, 2007; WHO, 2012c).

These problems have become the main impetus for an expeditious search for new alternatives, which would be acceptable for both the environment and health, for protection against insects. Among the existing alternative strategies aimed at decreasing pest populations, the use of pesticides based on plant extracts is currently one of the most promising. Derived from plant extracts, allelochemicals, i.e., compounds important in plant–insect interactions, are being more frequently considered for use in an alternative or complementary approach to synthetic insecticide treatments (Dubey, 2011). These allelochemicals are chemical mediators used in interspecies communication between plants and herbivores (Regnault-Roger, 1997). Indeed, some plants have evolved a broad spectrum of chemical and physical defences against diverse groups of insects (Ryan and Byrne, 1988a,b).

Plant extracts can affect pest behavior, including repelling the pest or prohibiting feeding activity, as well as pest physiology, including moulting and respiratory inhibition, growth and fecundity reduction, and cuticle disruption (Attia et al., 2013; Benelli et al., 2012a,b, 2013; Koul, 2008; Koul et al., 2008; Pavela, 2011a,b). Moreover, exposure to varying mixtures of the biosynthetically different compounds found in plant extracts can delay the evolution of resistance (Isman, 2000). Plant extracts are also an environmentally interesting tool because they are biodegradable and have minimal side-effects on non-target organisms, as well as on the environment (Isman, 2000, 2006; Pavela et al., 2013; Pavela, 2014a). Many plant extracts that contain substances with insecticidal effects also include a large group of the so-called essential oils.

2. Essential oils

Essential oils (EOs) are defined as volatile oils that have strong aromatic components and give a distinctive odour, flavor or scent to an aromatic plant. EOs are produced by more than 17,500 aromatic plant species commonly belonging to many angiospermic families, e.g., Lamiaceae, Rutaceae, Myrtaceae, Zingiberaceae and Asteraceae (Regnault-Roger et al., 2012). EOs are the by-products of plant metabolism and are commonly referred to as volatile plant secondary metabolites. The compounds of EOs are synthesized and stored in complex secretary structures, viz., glandular trichomes, secretory cavities, and resin ducts, and are present as droplets of fluid in the leaves, stem, flowers and fruits, bark, or roots of plants (Fahn, 2000).

In nature, the aromatic characteristics of EOs serve various functions for the plants, including: (i) attracting pollinators and beneficial insects, (ii) protecting them from heat or cold, and (iii) utilizing chemical constituents in the oil as defence materials against pests and/or microorganisms.

EOs are very complex natural mixtures which can contain about 20–60 components at quite different concentrations. They are characterized by two or three major components at fairly high concentrations (20–70%) compared to others components present in